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OUTLOOK FOR THE MACKEREL FISHERY IN 1931 [1]

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INTRODUCTION

PURPOSE

The purpose of this report is to forecast the most probable abun-ance of mackerel in 1931. The forecast is based on the changes hat have occurred during the last five years with a regularity that ndicates controlling principles which may be expected to operate n the future as they have in the past. But nature rarely repeats erself exactly. Variations have been noted during the past five ears and may be expected to occur in the future. During the short erm of these studies it has been possible only to gage variability y the comparison of a few repetitions of similar events.

Although certain events have recurred regularly enough to form basis for looking forward toward their repetition in the future, ne important feature has so far defied our efforts to connect cause nd effect closely enough to serve prediction purposes; that is, the bundance of yearling mackerel known to the trade as "blinks" nd "tinkers." In some years there are practically none of these; n other years they afford large catches. So far we have been unable o find evidence in one year that would indicate the abundance of

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yearlings to be expected the following year. Therefore, our predictions must be limited to the larger mackerel weighing 1 pound or more.

Though the forecast lacks definiteness, the fluctuations in the mackerel fishery have been so extreme that even this narrowing down of possibilities appears to have practical value warranting the publication of certain results in advance of an exhaustive technical report on the mackerel studies. Since it is admittedly a pioneer attempt, the reasons for all estimates will be discussed as thoroughly as space permits in order that he who chooses to study the question critically may make his own appraisal of the situation.

THE MACKEREL FISHERY

Distribution.—The mackerel, *Scomber scombrus*, ranges along the American coast from North Carolina to Newfoundland. United States fishermen make most of their catches between Virginia and Maine with a number of vessels making one or two trips to the offing of Nova Scotia. The latter fishery is locally termed "Cape Shore" by the fishermen and is so designated in this report. The only region having mackerel in abundance and not visited by the United States fishermen in recent years is the Gulf of St. Lawrence. Hence the United States fishery may be assumed to cover nearly the entire normal range of the mackerel (on this side of the Atlantic.)

There is a decided seasonality in the runs of mackerel. The fishing always begins in April when the mackerel are found off the Virginia coast. A month later they are off the New Jersey and Long Island shores, and by the first of June the fishing is concentrated off southern New England. At that time mackerel also appear off the coast of Nova Scotia and some of the seiners make trips to the Cape Shore while the remainder continue to fish off southern New England. By the end of June the mackerel disappear from south of Cape Cod and virtually all fishing is done in the Gulf of Maine. During the month of July most of the fishing takes place in the offing of Cape Cod but soon thereafter spreads northward often to Monhegan, Me.

Methods of fishing.—Mackerel are caught by a number of forms of gear. Chief among these is the purse seine, next the gill net, and lastly, several forms of shore gear such as pound nets and floating traps. The offshore fishery, prosecuted mostly by boats of 5 net tons and over (as measured by the United States Customs Service), employs only purse seines and gill nets. This branch of the fishery is the mainstay of the American market. Landings are made at relatively few ports, and it is possible to secure statistics and samples of the catch through the efforts of a few field observers. Therefore, our data relate mainly to the vessel fishery. The pound nets and traps are operated at widely scattered places; their catch is sold locally, and therefore is not susceptible to thorough observation by a small staff. Since it accounts for a relatively small catch, the omission of the shore fishery is not serious.

Seining.—The purse seine is an ingenious contrivance by means of which a school of fish is completely surrounded by netting. In the mackerel fishery the adjective is dropped and the gear is called a seine; the method of fishing is called seining; and the vessel using

ıis method is called a seiner. For the sake of brevity these terms re adopted in this report. The vessel using a seine cruises over the shing grounds with a member of the crew posted at the masthead ɔoking for schools of mackerel. When one is sighted the crew mans seine boat and a skiff or dory. One end of the seine is buoyed by ıe skiff while the remainder of the seine is paid out over the stern f the seine boat while the latter is towed around the school by the essel. When the two ends of the seine are brought together the ɔwline is cast off and the vessel stands by while the seine is "pursed" y means of a line running through rings at the lower border of the ɜine. A weight or tom is run down the purse line to facilitate ursing and to hold the lower border of the seine in the proper depth. ıfter pursing, enough of the netting is hauled in to concentrate the ıackerel in one portion of the seine, the vessel comes alongside, and ıe fish are bailed to the deck of the vessel.

Mackerel seining has a number of peculiarities that must be recog-ized when gaging abundance by means of the seine catch. They ɜvolve about the essential fact that the fish must be sighted before ıey are caught. In the first place this means that good fishing epends on the presence of schools at the very surface of the sea. 'he mackerel need only descend to deeper levels to escape the fishery. 'his undoubtedly happens at times when the sea seems devoid of ıackerel. Then too, the fishery is very sensitive to weather condi-ons, for the visibility of schools is affected by the roughness of the ɜa and the quality of the light. In the spring and fall fishing is one only on dark nights when the mackerel schools cause a glow 'hich is generated by the myriads of luminescent organisms as ıey are disturbed by the movement of the mackerel. On moonlight ights, the luminescence is so much less conspicuous that practically o seining is done. During the summer months seining is done in ıe daytime when the mackerel schools show as dark patches below ıe surface or by the rippling of the water as they break the surface.

Practically all sizes of mackerel may be caught by seiners, but it ; possible to distinguish the size of fish before setting the seine and ıe small ones (blinks and tinkers) are avoided when prices are ɔw. There appears to be a tendency for underrepresentation f the largest sizes, perhaps because at times they appear to be more ɜattered and swimming deeper than the medium and small sizes.

Netting.—Second in importance is the method of fishing termed netting." A completely descriptive name would be "drift gill etting" for the nets consist of vertical walls of webbing with upper ɔrders held at the surface by cork buoys and lower borders held own by leads along the foot line. They are set out end to end in ɔng strings. The mackerel are caught when their heads enter ıe meshes and can not be withdrawn. The nets are usually set in ıe evening and hauled in the morning.

Netting takes place in two distinct seasons. The principal catch made south of Cape Cod in April and May where the netters fish ırgely on the moonlight nights. They report that the luminescence ɔ dark nights renders the nets too conspicuous for effective fishing. he spring season extends into June in Massachusetts Bay. It then ɜrminates to be resumed again in October, November, and December, 'hen most of the fishing is done in the offing of Cape Ann.

There is a decided tendency for netters to catch the larger sizes of mackerel. They never catch blinks or tinkers, and the numbers of medium-sized fish are usually well below the number of large fish caught.

HISTORY OF PRODUCTION

Perhaps no fishery of equal commercial importance has been subject to more extreme variation in productivity than has the mackerel fishery off the coast of North America. It has yielded as high as 120,000,000 pounds in 1884 and within two years declined to a mere 20,000,000-pound catch. In 1910 the vessel catch was only 4,000,000 pounds but again in 1926 46,000,000 pounds were caught. The production curve given in Figure 1 illustrates this variability.

A conspicuous feature of the curve is the well-sustained increase since 1925. These yields, although high compared with those of the

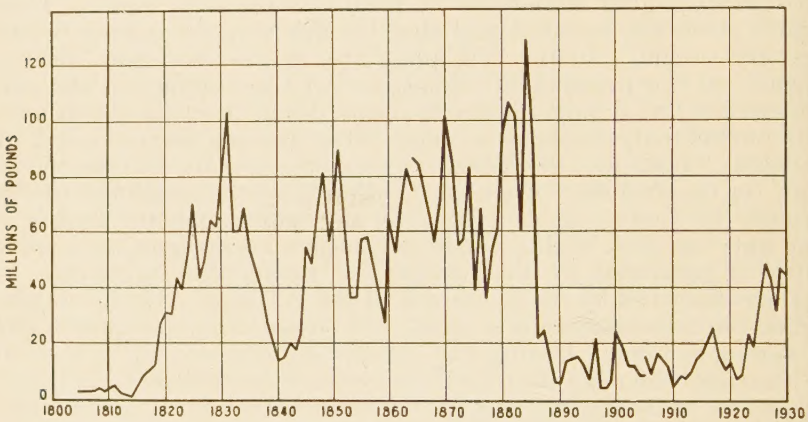

FIGURE 1.—Annual catch of mackerel by American vessels, 1804–1930. Data for 1804 to 1864 consist of total quantity of salt mackerel inspected in Massachusetts; data for 1864 to 1905 consist of the salt mackerel catch of New England; data for 1905 to date consist of the total landings of the American mackerel fleet. All quantities were converted to the basis of fresh round mackerel

years between 1885 and 1925, are none the less considerably below the best yields of the period ending in 1884. It is pertinent to inquire whether these yields represent a complete or only a partial restoration of the abundance of mackerel which characterized the early years of the fishery. Methods of fishing and distribution have changed so greatly that exact comparison is difficult. The modern fleet, although consisting of fewer vessels, has the advantage of auxiliary power. Perhaps the greatest difference is in marketing methods. Formerly, virtually the whole catch was salted; recently nearly the whole catch has been landed fresh. The effect of the change has been threefold. The wider markets reached by the salted product were probably capable of absorbing greater quantities of mackerel than can be marketed profitably at present, thus causing a greater incentive to intensive fishing. Fishing could be carried on with unabated vigor during the parts of the season when mackerel were most easily caught. During recent years, however, the fleet oc-

ionally has been forced to curtail production at the very times when ishing is best, for fresh fish markets are readily glutted. Finally, lthough at first thought it would appear that modern vessels, quipped with auxiliary power would waste less time in running etween the fishing grounds and port, it is probable that the reverse s the case, for the demand for fresh fish requires that each catch, hough it fall far short of the capacity of the vessel, be landed promptly.

In any case, whether recent yields represent a complete or only a partial restoration of abundance, there can be no doubt that a considerable increase in abundance has occurred. Since no protection has been afforded the mackerel for many years, it is apparent that the increase has been due to natural causes.

FLUCTUATIONS AND THEIR CAUSES

Studies on the European mackerel have established the dependence of the catch on hydrographical and meteorological conditions. For instance, Allen [2] and Russell [3] have shown the connection between February and March sunshine and May catches in the mackerel fishery off the south and west coast of England; and Jensen [4] has shown a close correlation between September water temperature and mackerel landed at Copenhagen from the sound and eastern Baltic during September.

We have not yet found any unmistakable connection between the success of the American fishery and environmental conditions. Although the weather and the hydrographic conditions undoubtedly effect the availability of mackerel and cause local and temporary changes in the catch, our data indicate that there is a more profound influence controlling the annual catch; that is, the fluctuating abundance of mackerel in the sea.

It is not surprising that there should be this discrepancy between European and American findings. The correlations described in the above European references apply only to certain times and certain localities. Nowhere has there been demonstrated a connection between the abundance over the whole range during the whole season, and environmental conditions. The United States fishery covers nearly the whole range of the mackerel in the Western Atlantic and apparently, at one time or another during the season, the mackerel are caught in proportion to their abundance, notwithstanding instances of exceptional abundance or scarcity at certain times and places.

YEAR-CLASS DOMINANCE

Fluctuations in the size of a population of any kind, anywhere, depend on birth rate and death rate. Where the former exceeds

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[2] Allen, E. J. Mackerel and Sunshine. Journal, Marine Biological Association, N. S., vol. 8, 1907–1910, pp. 394–406.

[3] Russell, E. S. Report on log-book records relating to mackerel, pilchards, and herring, kept by fishermen during the years 1895–1911. Board of Agriculture and Fisheries, Fishery Investigations, Series II, Vol. III, No. 1, 1915.

[4] Jensen, A. J. C. On the influence of hydrographical factors upon the yield of the mackerel fishery in the sound. Report of the Danish Biological Station. Copenhagen, 1930.

the latter, the population will increase, and conversely, where the latter exceeds the former, the population will decline. Where consideration is limited to a certain area, migrations into or from the area must also enter into the net result. The mackerel investigations have been essentially a study of the first two points: Birth rate and death rate. Migrations have been ignored for the time being because our field of observation includes almost the entire range of the western Atlantic race of the species, and because it

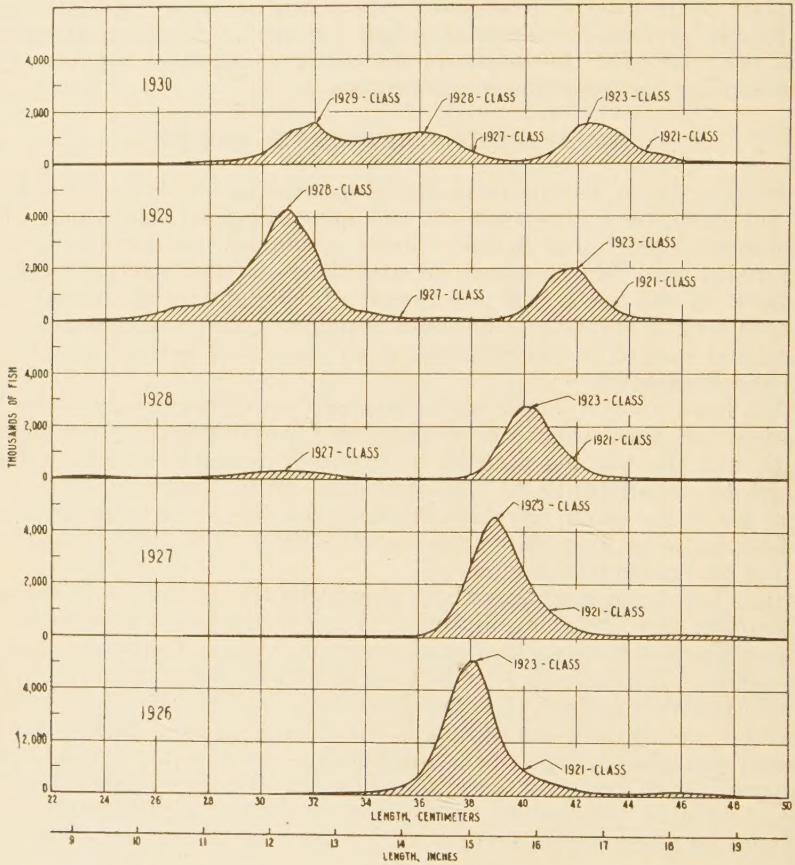

FIGURE 2.—Sizes of mackerel caught by seiners, 1926–1930. The areas under the curve are proportional to the numbers of mackerel caught

has not been necessary to resort to any extensive migration theories to account for the major phenomena observed.

Since the nature of the population precludes any direct count of births or deaths, various indirect means have been employed to estimate these equivalents. Practically the only means of studying the mackerel population is through the data made available by the activities of the commercial fishing fleet. This forms our instrument of observation, through which a number of pertinent facts may

be determined. The principal ones used in this report are the quantities of mackerel caught and the sizes or ages of the fish making up the catch. In other words, the fishing fleet provides a quantitative and qualitative sampling of the population. Thanks are due the fishermen who have secured for us many items of information, often at considerable expenditure of time and trouble.

From the reports of quantities of mackerel landed and from measurements of thousands of mackerel taken at random from the

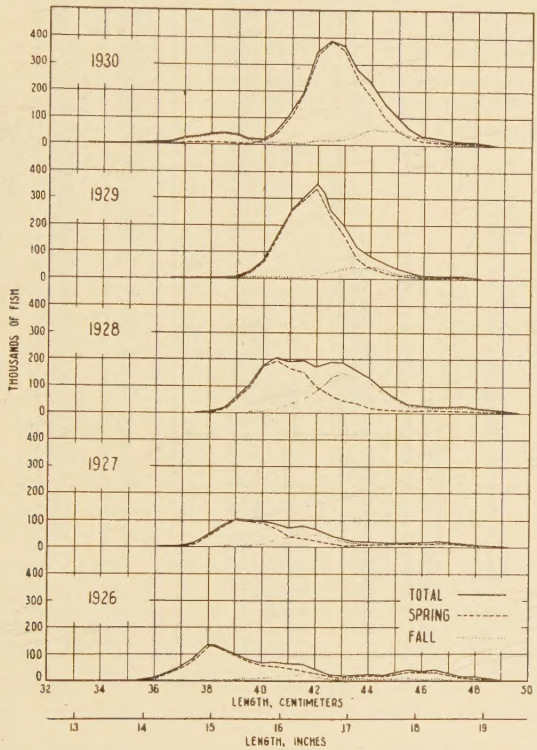

FIGURE 3.—Sizes of mackerel landed by netters, 1926–1930. The areas under the curves are proportional to the numbers of fish landed

catch, there has been determined by suitable compilations the number of mackerel of each size (in half-centimeter groupings) landed during the past five years. These data are given in Tables 1 and 2 and are shown graphically in Figures 2 and 3. The length frequency statistics cover the period from 1926 to 1930, inclusive. Data are available for part of the 1925 season also, but have not been included in the tables though some features of the 1925 season will enter the text discussions.

TABLE 1.—*Sizes of mackerel in the seine catch annually, 1926–1930, weighted according to the quantities caught*

[Numbers represent thousands of fish—that is, 000 omitted]

Length in centimeters	Frequencies					Length in centimeters	Frequencies				
	1926	1927	1928	1929	1930		1926	1927	1928	1929	1930
15.0						35.0	200	13	4	181	1,075
15.5				6		35.5	362	14	2	137	1,146
16.0				6		36.0	710	55	3	112	1,138
16.5				6		36.5	1,530	168	7	100	1,191
17.0				46		37.0	2,734	570	18	106	1,053
17.5				52		37.5	4,365	1,357	45	81	723
18.0				58		38.0	5,062	2,796	189	83	493
18.5				40		38.5	4,410	4,005	520	43	292
19.0				11		39.0	2,792	4,519	1,270	53	188
19.5						39.5	1,456	3,657	2,223	158	98
20.0				1		40.0	966	2,562	2,737	447	139
20.5				1		40.5	678	1,522	2,624	975	214
21.0						41.0	526	969	1,814	1,664	447
21.5				3		41.5	339	619	1,174	1,919	799
22.0			7	8	2	42.0	222	355	611	2,003	1,433
22.5			31	12	3	42.5	116	183	314	1,364	1,474
23.0			48	29	2	43.0	75	114	162	836	1,406
23.5			32	38	3	43.5	47	68	105	423	1,222
24.0			8	69	10	44.0	51	65	52	243	857
24.5			1	81	12	44.5	73	67	44	142	459
25.0				132	21	45.0	94	88	37	93	379
25.5				159	32	45.5	90	115	35	62	256
26.0			1	318	30	46.0	106	74	36	60	117
26.5			6	419	49	46.5	75	96	40	42	67
27.0			10	519	34	47.0	86	81	46	56	77
27.5		1	32	536	60	47.5	57	57	39	42	61
28.0			55	750	75	48.0	36	49	25	29	54
28.5		1	100	1,071	70	48.5	29	39	21	21	37
29.0		1	145	1,529	93	49.0	18	16	16	24	33
29.5	5	1	176	2,118	213	49.5	23	13	9	12	14
30.0	10	1	257	2,769	345	50.0	10	5	4	10	17
30.5	8	1	253	3,856	770	50.5	3	6	3	3	3
31.0	9	1	317	4,206	1,172	51.0	2	1	1	4	4
31.5	6	2	263	3,585	1,305	51.5	1	3	1	1	1
32.0	11	2	238	2,892	1,513	52.0	3		2		1
32.5	15	2	138	1,549	1,195	52.5	1				
33.0	26	10	83	867	930	53.0				3	
33.5	53	6	52	434	853	53.5			1		
34.0	79	4	23	370	955						
34.5	107	6	10	221	973	Total	27,677	24,360	16,520	40,299	27,688

TABLE 2.—*Sizes of mackerel in the net catch annually, 1926 to 1930, weighted according to the quantities caught*

[Numbers represent thousands of fish—that is, 000 omitted]

Length in centimeters	Frequencies														
	1926			1927			1928			1929			1930		
	Spring	Fall	Total	Spring	Fall	Total	Spring	Fall	Total	Spring	Fall	Total	Spring	Fall	Total
33.5	----	----	----	----	----	----	----	----	----	----	----	----	2	----	2
34.0	----	----	----	----	----	----	----	----	----	----	----	----	3	----	3
34.5	----	----	----	----	----	----	----	----	----	----	----	----	2	----	2
35.0	----	----	----	----	----	----	----	----	----	----	----	----	2	1	3
35.5	3	----	3	----	----	----	----	----	----	----	----	----	5	----	5
36.0	10	----	10	1	----	1	----	----	----	----	----	----	4	1	5
36.5	30	----	30	2	----	2	----	----	----	1	----	1	7	2	9
37.0	51	----	51	4	----	4	----	----	----	1	----	1	8	13	21
37.5	86	----	86	19	----	19	1	----	1	3	----	3	6	21	27
38.0	132	----	132	43	----	43	3	----	3	----	1	1	7	32	39
38.5	122	----	122	75	2	77	20	----	20	1	1	2	6	39	45
39.0	100	1	101	97	3	100	56	----	56	3	2	5	3	32	35
39.5	70	5	75	93	4	97	100	1	101	23	4	27	5	14	19
40.0	56	7	63	84	9	93	169	4	173	63	3	66	12	6	18
40.5	54	14	68	62	21	83	192	11	203	160	1	161	41	5	46
41.0	46	16	62	36	33	69	166	26	192	252	2	254	106	5	111
41.5	39	22	61	30	45	75	152	44	196	298	6	304	190	5	195
42.0	28	13	41	21	45	66	95	75	170	339	13	352	331	15	346
42.5	17	6	23	13	32	45	67	120	187	236	22	258	372	16	388
43.0	12	4	16	8	21	29	47	141	188	168	35	203	351	18	369
43.5	11	4	15	7	13	20	36	122	158	79	40	119	239	34	273
44.0	18	2	20	8	9	17	18	114	132	42	43	85	176	52	228
44.5	15	4	19	8	7	15	13	72	85	26	35	61	103	50	153
45.0	24	5	29	10	4	14	10	47	57	13	29	42	51	52	103
45.5	30	7	37	11	6	17	8	23	31	10	17	27	26	31	57
46.0	29	3	32	9	8	17	9	19	28	6	7	13	11	20	31
46.5	30	7	37	13	9	22	10	14	24	5	5	10	14	14	28
47.0	22	1	23	11	8	19	7	17	24	8	3	11	9	8	17
47.5	14	----	14	7	5	12	6	22	28	8	2	10	6	7	13
48.0	13	1	14	5	2	7	5	13	18	3	1	4	8	4	12
48.5	5	----	5	3	2	5	3	10	13	3	----	3	1	2	3
49.0	3	----	3	1	1	2	2	5	7	----	----	----	3	1	4
49.5	1	----	1	2	1	3	2	4	6	1	----	1	2	----	2
50.0	----	----	----	2	----	2	----	----	----	----	----	----	----	----	----
50.5	----	----	----	----	1	1	----	----	----	----	----	----	----	----	----
51.0	----	----	----	----	----	----	----	1	1	1	----	1	----	----	----
51.5	1	----	1	----	----	----	----	1	1	----	----	----	----	1	1
Total	1,072	122	1,194	685	291	976	1,197	906	2,103	1,753	272	2,025	2,112	501	2,613

It is evident from these figures that the sizes fall into pronounced groupings. Through detailed study of such groupings as shown in Figure 2 and the examination of the scales from thousands of mackerel, it has been found that each mass group consists of fish mainly of one year class; that is, mainly fish of a single year's spawning. For convenience we shall designate the classes by giving the year in which they were spawned; for instance, 1923 class refers to the mackerel that resulted from the spawning of 1923. Where there are several year classes separated in age by only one or two years, and one of them is much more numerous than the other, the lesser ones are submerged, so to speak, in the greater. Thus the 1921 class is merged into the group characterized by the more abundant 1923 class, and in 1930 the few 1927 class mackerel are lost in the grouping made up of the very much more abundant 1928 class.

Considering each year's frequency as shown by Figure 2 we see that in 1926 practically all the mackerel were between 35 and 42 centimeters (14 and 16½ inches) long, with most of them 36 to 39

centimeters (14¼ to 15½ inches) long. Fish of the 1923 class made up this group. Those around 39 to 42 centimeters (15½ to 16½ inches) were of the 1921 class. Since the areas of the curves are proportional to the number of fish of each size taken in the catch, the dominance of the year's catch by the 1923 class is brought out in a striking manner.

In 1927 we find the same group present, but somewhat larger due to a year's growth.

They are again present in 1928, and here, too, they register some growth since the previous year. In addition, there is another group 28 to 33 centimeters (11 to 13 inches) long. These are mackerel of the 1927 class appearing in the seine catch in 1928 for the first time, as yearlings.

In 1929 we again find the 1923 and 1921 classes forming distinct groups at lengths consistent with their growth since the previous year. A few mackerel of the 1927 class are present in the neighborhood of 37 centimeters (14½ inches). But the outstanding feature of the 1929 frequency distribution is the tremendous group extending from 25 to 35 centimeters (10 to 13¾ inches). These were the yearling mackerel of the 1928 class and constituted the largest contingent to enter the fishery since the appearance of the 1923 class.

In 1930 we find the groups represented in the previous year again present, though the mackerel composing them are of appropriately larger sizes. The 1923 and 1921 classes are still strongly represented, forming a group at 40 to 46 centimeters (16 to 18 inches). The 1927 class, small to begin with, has dwindled until it is hardly perceptible, but appears to cause a slight bulge at 38 centimeters (15 inches). The 1928 class, though notably reduced since the previous year, constitutes a distinct grouping between 34 and 38 centimeters (13½ and 15 inches). A noteworthy addition in the form of the 1929 class appears at 30 to 33 centimeters (12 to 13 inches).

We have seen that during the 5-year period certain year classes have provided many mackerel and others have failed to make significant contributions to the catch. Turning to the production curve (fig. 1) we shall see how the differences in the abundance of the various year classes have caused the changes in the annual yield. In 1922 the fishery was at a rather low ebb; but in passing to 1923 there is a moderate rise, doubtless occasioned by the entrance of the 1921 class into the fishery as 2-year-old mackerel. The great increase in catch between 1924 and 1926 was due to the entry of the 1923 class as shown by measurements made during a portion of the 1925 season and the entire 1926 season. Since the spawnings of 1924, 1925, 1926, and 1927 failed to produce many mackerel and the 1921 and 1923 classes inevitably declined due to mortality, the catch declined between 1926 and 1928. But in 1928 another large year class was produced, and the next year the mackerel of this class were large enough to handle commercially; hence there was a sharp recovery in 1929. In 1930 the decline in abundance of the 1921, 1923, and 1928 classes was almost offset by the contribution of mackerel of the 1929 class appearing in the fishery for the first time.

These facts justify the thesis that the fluctuations in the yield are due mainly to changes in abundance of mackerel. The increase in 1926 may be safely attributed to the extraordinary numbers of mackerel added to the population. The moderate declines in 1927

nd 1928 are exactly what might be expected, since natural mortality nd the toll exacted by the fishery were not compensated for by any naterial additions. In 1929 and 1930 the natural course of the de- line was halted by the addition of two new increments, the 1928 and 929 classes.

PREVIOUS FORECASTS AND PRESENT DIFFICULTIES

In tracing the effects of year-class dominance on the annual catch he reader will have noted variations in the response of the fishery to he advent of new year classes. For instance, the 1923 class did not naterially increase the catch until 1925, when it was 2 years old, and ct produced a still larger catch in 1926. On the other hand, the 1928 lass increased the catch in the very next year and by its second year vas declining.

These differences in behavior of the year classes have been the chief ource of difficulty in forecasting future abundance. In the spring of 928, when the 1923 and 1925 classes had been observed in the fishery or three years and it appeared fairly certain that a new year class vas not yet due to appear, we predicted [5] a decline in the catch, which vas borne out by subsequent events; though the 1927 class augmented he population, their number were too few to offset the decline in the 923 and 1921 classes.

In the spring of 1929 it was pointed out [6] the 1923 and 1921 lasses must continue to decline, but that it was uncertain whether he 1927 class would make a large enough contribution to offset the lecline. As it turned out, the catch was much larger—due not to the 1927 class, but to the very large 1928 class that made its appearance or the first time.

Again in the spring of 1930 the prospects for the coming season vere discussed.[7] At that time it appeared that the outstanding actor would be the 1928 class which, on the basis of the previous ear's showing, appeared to greatly exceed the important class of 1923. But, on the contrary, this class proved to be only moderately mportant in 1930 while the 1923 class furnished the expected quota nd the 1929 class also appeared in considerable numbers.

PROSPECTS FOR 1931

Reviewing these past experiences it is apparent that considerable atitude must be allowed for variation in the contribution to the atch of the younger year classes. In order to express the possible ariations in the 1931 forecast, each year class has been studied to rrive at the "most probable" number to be expected; also the 'highest probable estimate" and the "lowest probable estimate."

It has already been pointed out that seine and net fisheries differ s to their selection of sizes, hence of year classes. It is therefore ecessary to consider the two kinds of fishing separately.

SEINE FISHERY

The 1923 and older classes.—We have seen that throughout the last five years an important portion of the catch has been made up

[5] Fishing Gazette, vol. 45, No. 4, April, 1928.
[6] Fishing Gazette, vol. 46, No. 4, April, 1929. Fishermens Own Book and Fishing Equipment News, vol. 9, No. 3, March, 1929.
[7] Fishing Gazette, vol. 47, No. 4, April, 1930.

of a group including 1923 and 1921 classes together with a few older fish. While there is little basis for estimating the relative importance of these components from an inspection of the frequency distribution in Figure 2, a detailed study of frequencies representing various localities, and time intervals in 1926 and 1927 has resulted in the estimates of year-class composition given in Table 3 and Figure 4. From this it is apparent that the 1923 class forms the bulk of the group (86.5 per cent) with the 1921 and older classes decidedly less numerous. Hence we may consider the statistics on this group as virtually representing the 1923 class and treat them as a single unit.

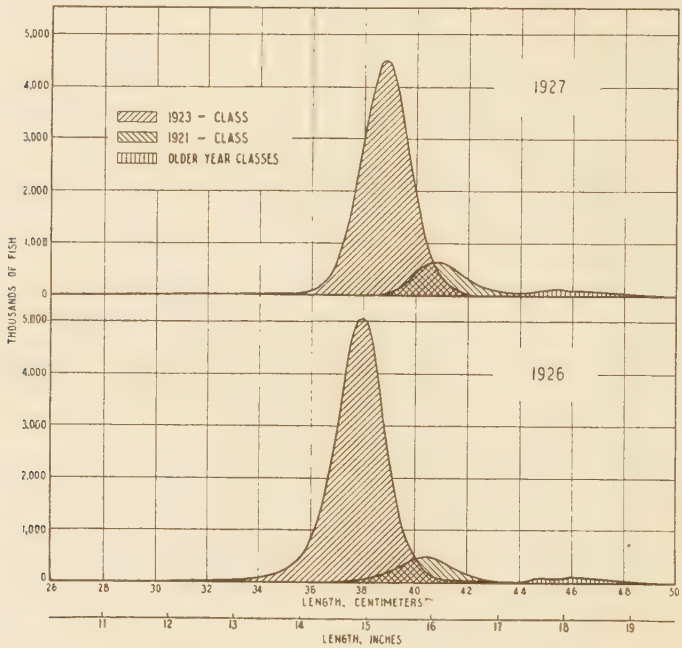

FIGURE 4.—Length-frequency distributions of the several year classes in 1926 and 1927. The areas under the curves are proportional to the numbers of fish landed

TABLE 3.—*The approximate year-class composition of the group comprised of mackerel of the 1923 class and older mackerel in 1926 and 1927*

Year	1923 class	1921 class	Older classes	Total
	Number	*Number*	*Number*	*Number*
1926	24, 242, 000	2, 534, 000	794, 000	27, 570, 000
1927	20, 579, 000	2, 984, 000	772, 000	24, 335, 000
Average	22, 410, 000	2, 759, 000	783, 000	25, 952, 000
Per cent	86. 5	10. 6	3. 0	100. 1

Knowing the number of mackerel of the 1923 and older classes caught by the seiners each year since 1926, it should be possible to judge their annual rate of decline and thus reckon their probable

bundance in 1931. Unfortunately, the total catch is not necessarily good index of their abundance, for significantly different numbers f vessels may have engaged in the fishery in different years so that ne total catch may have been affected by the size of the fleet as well s by the abundance of mackerel. It is not a simple matter to arive at the relative intensity of the fishery from year to year, for any vessels fish during only a portion of the season, while different essels have different catching efficiency.

Appreciating the necessity of arriving at some measure of relative abundance and realizing that the imperfections of our data equire as many checks on their interpretation as may be devised, e have computed relative catches of the 1923 and older broods ccording to several different methods with the results given in able 4. In the first column is shown the annual catch by the entire eine fleet. These data have the merit of being available for the ntire 5-year period; and including as they do, all catches, there is no uestion of any distortion of data by arbitrary manipulation. However, changes in the fleet may seriously affect the picture, though on he whole, we know of no marked differences in the number and haracter of the vessels during the period.

ABLE 4.—*Relative abundance of the 1923 and older classes according to two series of data*

[1929 (base year) = 100]

Year	Total catch all seiners		Catch per regular seiner	
	Number	Index	Number	Index
26	27, 570, 000	258		
27	24, 335, 000	228		
28	14, 229, 000	133	231, 000	128
29	10, 667, 000	100	181, 000	100
30	9, 555, 000	90	151, 000	83

To arrive at the average catch per seiner it was necessary to separate the seiners which fished regularly and those that were in the shery only a portion of the time. This has the fault of involving he determination of which vessels should be considered "regular"—decision that is not always easy and which may be considerably olored by personal opinion. Furthermore, the data are available or only the last three years of the period. However, the close orrespondence of total catch and average catch per seiner when educed to index numbers, indicates that fleet changes can not have nfluenced the total catch very much. On the other hand, neither ethod takes into account any changes of fishing effort that might esult from economic influences or weather conditions.

Perhaps the average catch per vessel per day of actual fishing ould be the ideal measure of abundance if sufficiently complete nformation were available for a reliable determination of its value. he only sources of detailed information upon which to base a calcuation of average catch per day fishing were a number of log books ut at our disposal through the kindness of mackerel fishermen. hese proved to be too few to yield reliable results. It is to be

hoped that sufficient log-book records will be kept in the future to permit of this kind of measure of abundance.

It therefore appears for the present that we must rely on the catch per regular seiner and the total catch for all seiners. Not knowing which of the two series is the more reliable, we might calculate the decline according to each series and take the average of the two. If we do this, we must conclude that the decline of this group of year classes was about 25 per cent between 1928 and 1929 and about 14 per cent between 1929 and 1930. Since the percentage mortality appears to be lessening we might expect a still smaller decrease between 1930 and 1931, let us say about 10 per cent. However, the relative decline of 25 per cent and 10 per cent may not be significant. It is conceivable that the rate may be more nearly constant and that the lesser decline between 1929 and 1930 might have been due to extraneous circumstances such as bad weather. Even so it appears that the highest reasonable decline would be not more than 25 per cent. By similar reasoning it could be shown that the lowest reasonable decline would be in the nature of 5 per cent. Taking the three rates and applying them to the 1930 figure we would get 7,000,000, 8,500,000, and 9,000,000, respectively, as the "lowest estimate," "most probable estimate," and "highest estimate" of the number of mackerel to be expected from the 1923 and older broods during 1931.

The 1927 class.—The 1927 class of mackerel first appeared in the fishery in 1928 when about 2,164,000 were caught. During the next season only 574,000 were landed, and in 1930 the numbers of this class were so low that they could not be distinguished by the methods of analysis available to us. Clearly we can not expect appreciable amounts from this brood during 1931.

The 1928 class.—In Table 5 are shown the data on relative abundance of 1928-class mackerel as indicated by the two methods of calculation that were discussed in the section on the 1923 and older classes. The number caught in 1928 is not significant for they were too small to be intensively fished at that time. Even in 1929 they were less desirable commercially than the older year classes, but were in demand nevertheless during the late summer when practically no larger mackerel could be caught by the fishermen. By 1930 they were medium sized and, of course, in full demand.

TABLE 5.—*Relative abundance of 1928-class mackerel*

Year	Total seine catch	Catch per regular seiner
	Number	*Number*
1928	127,000	
1929	28,833,000	487,00
1930	9,638,000	152,00
Per cent decrease in 1930	67	6

Noteworthy from this table is the sharp decrease between 1929 and 1930, ranging from 67 to 69 per cent depending on the method of calculation. Having experienced such a sharp decline in 1930, will this class suffer as greatly in 1931? We have very few data to indi

ate the answer to this question. Only two other year classes have passed through this stage since the beginning of these investigations: The 1923 class in passing from 1925 to 1926 and the 1927 class in passing from 1929 to 1930. Our data on 1925 are not complete enough to indicate beyond doubt the approximate number of mackerel of the 1923 class caught in that year, but it is quite certain that the 1923 class made up the bulk of the catch both in 1925 and 1926. The increase in total poundage from 34,000,000 in 1925 to 47,000,000 in 1926 is a fairly clear indication that the 1923 class did not seriously decline between its second and third years, even though allowance be made for a larger fleet fishing in 1926 than in 1925.

On the other hand, the 1927 class in passing from the second to the third year practically dropped out of sight. This need not be taken too seriously, however, for even though their numbers had been nearly equal in 1930 and 1929, the great number of 1928 class mackerel would have the effect of concealing the presence of the 1927 class in the frequency distributions.

All things considered it appears that the highest expectations from the 1928 brood in 1931 would be around the same number as were present in the 1930 catch, the lowest expectation would be about a 70 per cent decrease from 1930. The most probable expectation should be in between these extremes—let us say a 35 per cent decrease. Application of these rates would give a high figure of 9,000,000, a low figure of 3,000,000, and a medium figure of 6,000,000 fish of this brood to be expected in the 1931 catch.

The 1929 class.—In 1930 seiners caught 8,487,000 mackerel of the 1929 class. When it is considered that during 1930 these were small mackerel, known to the trade as "blinks" or "tinkers," and not as desirable as larger fish, the numbers present in the catch are notable. What this promises for 1931 may be found perhaps by a comparison of the catches of other year classes at a similar age. These are given in Table 6.

TABLE 6.—*Comparison of catches of several year classes between their first and second seasons in the fishery*

Season in fishery	1927 class	1928 class
First	2,164,000	28,833,000
Second	574,000	9,638,000
Per cent decrease	73	67

One is immediately impressed with the close correspondence of the percentage decrease of 73 and 67 per cent in the 1927 and 1928 classes, respectively. If those two years are representative, a probable decrease would be indicated for the 1929 class on passing from its first to its second year in the fishery.

The possibility that the decrease should be more than 70 per cent seems remote. Allowing 10 per cent as an observational error an 80 per cent reduction of the 1929 class in 1931 might be taken as the lowest reasonable estimate.

But the above two classes are now the only ones of which we have record. Though our data on year-class composition of the catch

does not extend back to 1924 we know, nevertheless, that a large class was produced in 1923 and may have appeared in 1924. The catch of yearling mackerel is usually restricted to the months of August, September, and October. Assuming that all the mackerel caught during this period were of the 1923 class, the monthly statistics during 1924 indicate that there could not have been more than 6,000,000 fish of this class caught during those months. Yet in 1925 the measurements during part of the season indicate a catch of about 20,000,000 fish of the 1923 class. Allowing for increases in the fleet and errors in our estimates, it appears that the 1923 class provided at least double the number of mackerel in its second year that it did in its first year in the fishery. Of course, it can not be argued that the abundance doubled between the two years. Obviously the effort expended in trying to catch the small and low-priced yearling fish in 1924 was much less than that expended in catching the larger and higher priced 2-year-olds the following season. It is possible also that their distribution was unfavorable to a normal return on the fishing effort in 1924.

Whichever explanation one wishes to accept or whatever combination of the two appears most reasonable, the fact remains that there has occurred an instance in which the second year's catch of a year class has been higher instead of lower than the first year's catch. Therefore, we can not overlook the possibility of a larger catch of 1929-class fish in 1931 than was landed in 1930. As an estimate of the highest reasonable number to expect let us take twice the number caught in 1930.

Applying the estimates given in the foregoing paragraphs the most probable number of mackerel to expect from the 1929 brood in 1931 is 2,500,000, the highest figure would be 17,000,000, and the lowest 2,000,000.

The 1930 class.—Lacking any data concerning the size of the 1930 class of mackerel, it is impossible to make an estimate of the numbers to be expected in 1931. If any appear, they will be of blink or tinker sizes, occupying a distinctive place in the market and need not be confused with the adult mackerel weighing a pound or more apiece. The blinks and tinkers have usually appeared in August, September, and October, and should affect the fishery only during those months. In Table 7 are given the numbers of this category that were caught each year since 1926. It will be seen that the catch varies from practically none to about 30,000,000. This indicates the possibilities, should anyone care to consider them.

TABLE 7.—*Number of yearling mackerel (blinks and tinkers) caught by seiners 1926 to 1930*

Year	Number	Year	Number
1926	107,000	1929	23,833,000
1927	25,000	1930	8,487,000
1928	2,164,000		

Summary.—To summarize the data on seiners, there have been listed in Table 8 the numbers of mackerel of each year class caught annually since 1926 together with the estimates for 1931. It is

nceivable that each year class might yield the numbers indicated the high estimate or in the low estimate, but this is not at all tely. With three components in the catch and with each of them ving an equal chance to be higher or lower than the most prob-le figure, a study of possible combinations shows that there is ly 1 chance in 8 that they would all be lower or all higher an the most probable figure; and the possibility that all should ance to be at the highest estimate or all at the lowest estimate is any times more remote.

BLE 8.—*Numbers of seine-caught mackerel of each year class caught, 1926 to 1930, with estimates for 1931*

Year	1923 and older classes	1925 class	1926 class	1927 class	1928 class	1929 class
6	27,570,000	107,000	(1)			
7	24,335,000	(1)	25,000	(1)		
8	14,229,000	(1)	(1)	2,164,000	127,000	
9	10,667,000	(1)	(1)	574,000	28,833,000	225,000
0	9,555,000	(1)	(1)	(1)	9,638,000	8,487,000
1:						
High estimate	9,000,000	(1)	(1)	(1)	9,000,000	17,000,000
Most probable estimate	8,500,000	(1)	(1)	(1)	6,000,000	2,500,000
Low estimate	7,000,000	(1)	(1)	(1)	3,000,000	2,000,000

Negligible.

NET FISHERY

The net fishery is confined to the early spring and late fall. Its otal catch never approaches the seine catch, though the landings by etters may be considerable during the relatively short periods in hich they operate. A study of the numbers of mackerel of each size n the spring and fall fisheries as shown in Table 2 and Figure 3 eads to the conclusion that different year classes dominate in the two easons. The spring net fishery closely resembles the seine fishery in ne dominance of the 1923 class, while the fall net fishery has never ncluded appreciable numbers of fish from this class, but during the ast five years has been dominated by the 1921 and older classes. In 930 the 1928 class was also strongly represented in the fall netter atch.[8] Because of these differences it will be necessary to deal with ne two fisheries separately.

Spring fishery.—The numbers of fish (as well as the poundage) anded by netters in the spring has consistently increased during the ast four years. It is obvious that this can not have been due to ncreasing abundance of fish, because the catches have all been drawn ainly from the 1923 class, which can not logically be thought to ave increased in abundance. Several other explanations for the ncreased catch present themselves. For instance, the method of

[8] It is notable that the 1928 class mackerel resemble the 1921 class mackerel in appear-ig in the fall net fishery and that both differ from the 1923 class in this respect. It is lso a fact that the 1921 class dominated the Cape Shore fishery while the 1923 class has een virtually absent. These differences suggest the possibility that the 1921 and 1928 asses may be inherently different from the 1923 class for the 1921 and 1928 classes oth apparently decreased in passing from their first to their second years in the fishery hile the 1923 class apparently increased during the same stage in the fishery. We do ot understand these distinctions sufficiently to make use of them at the present time.

fishing appears to be more efficient for catching the larger fish. As the fish of the 1923 class grew larger from year to year they became increasingly "available" to this type of gear. Then too, the size of the fleet may have increased, though we have not yet had opportunity to study this feature sufficiently to give any data on the subject. Nor has adequate study been made of the effect of seine landings on the activity of the netter fleet, though we know in 1930, for instance, that the seiners were prevented from fishing during the height of the southern run and it was during this period that the bulk of the spring netter catch was landed.

Assuming that the spring netter fishery continues to draw mainly on the 1923 class, it appears that it must sometime begin to show the effects of decreasing abundance. We have already concluded that the 1923 class (as measured in the seine fishery) probably will be decreased by about 10 per cent. In this way we would arrive at a "most probable estimate" of 2,000,000 mackerel.

For a "high estimate" let us concede the possibility that increasing availability continues through 1931. This would raise the catch to about 2,500,000 fish. For a low estimate we may admit the possibility that the brood may decrease at the maximum rate of 25 per cent indicated in our study of the seine fishery for 1923 and older classes. This would result in a yield of about 1,500,000 mackerel.

Fall fishery.—In some ways it is more difficult to estimate the probabilities in the fall net fishery. For the last five years the 1921 and older broods have dominated this fishery, but in 1930 we find an addition in the form of the 1928 class. Data on the numbers of the 1921 and older classes landed by this fishery during the last five years do not show a significant trend in either direction, and the 1928 class has only been in the fishery once, so there has been no opportunity to establish its trend. It seems reasonable to suppose, however, that the 1921 and older classes may decline and that the 1928 class may yield greater numbers due to increased "availability" to the netters as they grow larger. To arrive at a "most probable" estimate it might be supposed that the two forces may offset each other and the 1931 catch remain the same as the 1930—approximately 500,000 fish. In arriving at a "high estimate" we must concede the possibility that the 1921 and older classes might yield the highest number on record—900,000. Furthermore, the 1928 class, through greater availability, might afford double the yield provided in 1930. The latter was about 200,000 mackerel, so that 400,000 might be caught in 1931. Adding the two together we arrive at 1,300,000 as a "high estimate." For "low estimate" we may consider the possibility of a natural decline of 25 per cent in the 1921 and older classes and a 70 per cent decline in the 1928 class. These are the possibilities arrived at through the study of abundance in the seine fishery. Adopting these, the resultant figure would be 200,000 fish of the 1921 and older classes, plus some 100,000 from the 1928 class—a total of 300,000. We may therefore conclude with an estimate of 500,000 as most probable, 1,300,000 as high estimate, and 300,000 as low estimate.

SUMMARY

We have estimated the most probable numbers of mackerel to expect from each year class in the seine and net fisheries in 1931; it

ly remains to translate these to poundage and add them as has en done in Table 9. When this is done we find that about 35,000,000 ounds are the most probable total for the 1931 catch. The high timates and low estimates have not been totaled, because the reali- tion of such extremes in the catch is exceedingly remote. As has en pointed out in an earlier section of this report, the likelihood of l year classes showing at the maximum or minimum is not great.

BLE 9.—*Summary of estimates of the most probable catch (exclusive of blinks and tinkers) in 1931*

Year class	Number	Average weight	Pounds
ne fishery:			
1923 and older	8,500,000	2.15	18,000,000
1928	6,000,000	1.50	9,000,000
1929	2,500,000	1.25	3,000,000
Total	17,000,000		30,000,000
t fishery:			
Spring—1923 and older	2,000,000	2.20	4,400,000
Fall—			
1921 and older	250,000	2.25	500,000
1928	250,000	1.50	400,000
Total	2,500,000		5,300,000
Grand total	19,500,000		35,300,000

If it may be assumed that the " most probable " estimates are three mes as likely to occur as are either the highest or lowest estimates, consideration of the possible combinations of the five units—seine tch of 1923 and older classes, seine catch of 1928 class, seine catch 1929 class, spring net catch of all classes, and fall net catch of all asses—leads to the conclusion that the probability of having either ie highest or the lowest catch would be 5^5, or 1 in 3,125.

If we are permitted to pursue this speculation further we might ssume that the difference (32,000,000 pounds) between the sum of ie high estimates and the sum of the low estimates is roughly equal three times the standard deviation of an imaginary normal proba- lity curve of the various combinations of high, low, and interme- iate values for each year class. Then one times the standard devia- on, or about 10,000,000 pounds, would include about 70 per cent of ie cases; or concretely there are 7 out of 10 chances that the abun- ance of mackerel in 1931 will be such as to provide a catch within 000,000 pounds of the predicted 35,000,000, and 1 in 3,000 chances iat the catch may differ from the prediction by as much as 16,000,000 ounds.

In conclusion, it should be emphasized that the estimates given for 931 do not take into account possible changes in the number of ves- ls fishing; the length of time they may stay in the fishery; the terruptions that might be caused by natural conditions, such as bad eather; and economic conditions, such as prices below the cost of roduction. These things may have an appreciable effect on the size f the catch and are relatively unpredictable at least from the bio- gical standpoint. Persons in touch with the fishery might make

their own estimates on the degree to which these events may alter the productivity of mackerel from time to time during the season.

Furthermore, we have not included in our estimates the probable catch of yearling mackerel, because there has been no method developed that enables us to measure the abundance of blink and tinker mackerel prior to the year in which they are due to appear in vessel catch. Perhaps a solution of this problem will be at hand when there has been established a method of measuring the abundance of larval mackerel and estimating their survival over the first winter. For this purpose the bureau's research steamer *Albatross II* has been engaged in hydrographic and plankton surveys of the spawning grounds for several seasons, but information has not yet been secured on enough seasons to be of practical use in forecasting.

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